

Engineering Design File

EDF-5734

PROJECT NO. 22901

TSF-09/18 V-Tanks Remediation Transport Tie-Down Analysis



ENGINEERING DESIGN FILE

EDF No.: 5734 EDF Rev. No.: 0 Project File No.: 22901

1. Title: TSF-09/18 V-Tanks Remediation Transport Tie-Down Analysis				
2. Index Codes:				
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4. EDF Safety Category: C.G. or <input type="checkbox"/> N/A SCC Safety Category: C.G. or <input type="checkbox"/> N/A				
<p>5. <u>Summary</u> . This Engineering Design File (EDF) shall evaluate the transportation requirements for the three 10,000 gallon V-tanks. Specifically, the cargo securement requirements of 49 CFR 393.102, <i>Federal Motor Carrier Safety Regulations</i>, shall be addressed in this EDF.</p> <p><u>Conclusions</u>: A tie-down design was completed based on the requirements of 49 CFR 393.102 (d) Equivalent Means of Securement. This requires a minimum of (4) tie down straps spaced along each of the 20-ft long tanks. Each tie-down strap shall have a minimum Working Load Limit (WLL) of 12,000 lbs and shall meet the requirements of the Web Sling and Tie down Association's Recommended Standard Specification for Synthetic Web Tie downs. (WSTDA-T1, 1998). The 4" wide straps are free at one end to all usage with the winches provided on the trailer (seven sliding winches are provided on each side). The other end of the straps are provided with hooks for securing to the trailer frame. Each strap will run from the trailer winch over the tank to the opposite side.</p>				
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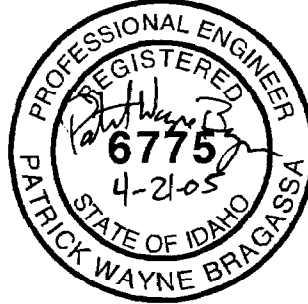
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13. Registered Professional Engineer's Stamp (if required)



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TSF-09/18 V-Tanks Remediation Transport Tie-Down Analysis

1. PURPOSE

The V-Tanks remediation project will remove and treat liquid waste from four underground steel tanks and store the treated waste temporary in consolidation tanks. The four underground tanks will be removed and the surrounding contaminated soils remediated. The waste will be pumped back into three of the 10,000 gallon V-tanks (V-1, V-2, V-3) and mixed with a solidification agent to stabilize liquid. The stabilized liquid will be consistent with a “granulized gel”. Once stabilized, the tanks with contents will be transported to the INEEL CERCLA Disposal facility (ICDF) for final disposal.

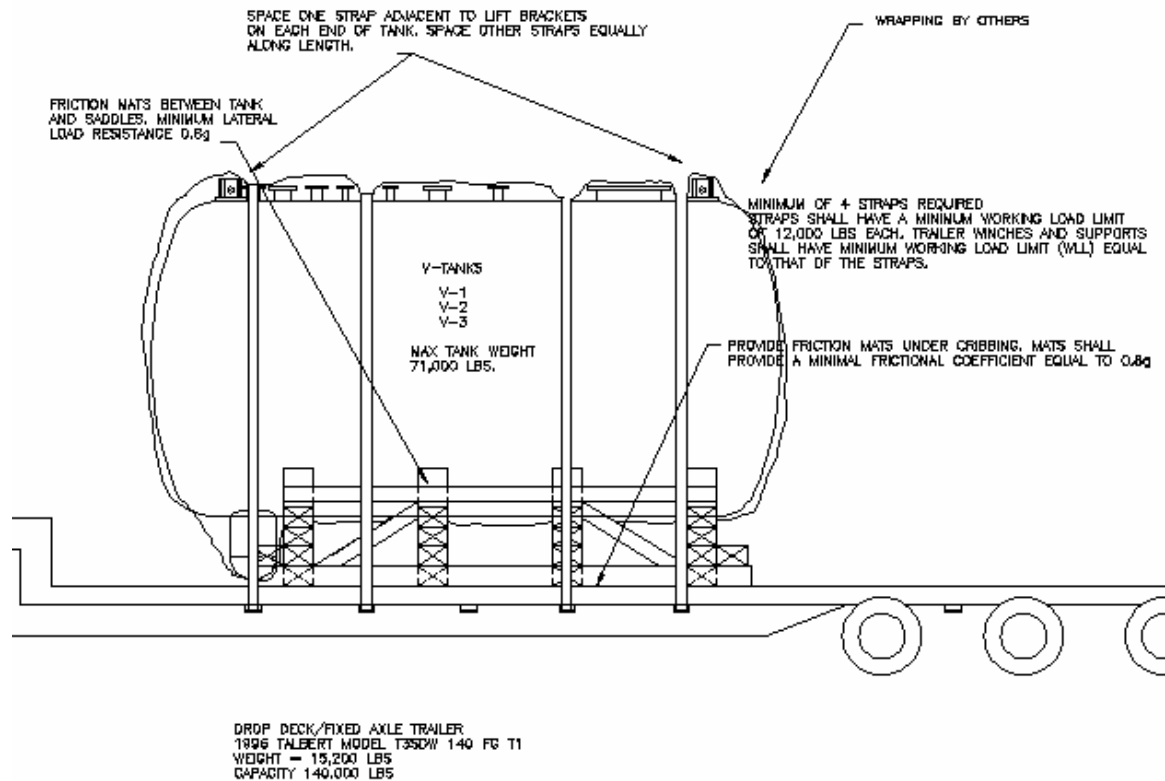
2. SCOPE

This Engineering Design File (EDF) shall evaluate the transportation requirements for the three 10,000 gallon V-tanks. Specifically, the cargo securement requirements of 49 CFR 393.102, *Federal Motor Carrier Safety Regulations*, shall be addressed in this EDF.

3. CONCLUSIONS/RESULTS

A tie-down design was completed based on the requirements of 49 CFR 393.102 (d) Equivalent Means of Securement. This requires a minimum of (4) tie down straps spaced along each of the 20-ft long tanks. Each tie-down strap shall have a minimum Working Load Limit (WLL) of 12,000 lbs and shall meet the requirements of the Web Sling and Tie down Association's Recommended Standard Specification for Synthetic Web Tie downs. (WSTDA-T1, 1998). The 4" wide straps are free at one end to all usage with the winches provided on the trailer (seven sliding winches are provided on each side). The other end of the straps are provided with hooks for securing to the trailer frame. Each strap will run from the trailer winch over the tank to the opposite side.

The cribbing design specified in EDF-5595 shall be used to support the tanks during transport. Each tank will be supported by (4) saddles (cradles), braced together in a frame. The saddles were designed to support the tank weight of 71,000 lbs on a bearing surface of 3000 psf. The saddles are designed to resist lateral forces of 0.8 g forward and rearward and 0.5 g sideways. Friction pads will be placed between the tank and support saddles to transfer lateral forces from the tank to the saddles. These friction pads shall have a lateral load resistance rating of 0.8g minimum. Longitudinal forces are transferred from the top of the saddle to the base by braces. Commercially available Friction mats are placed between the saddle base skid and trailer bed to transfer forces to the trailer structure. Friction mats shall have a minimum lateral load resistance of 0.8 gs.



TRANSPORT SKETCH

4. SAFETY CATEGORY

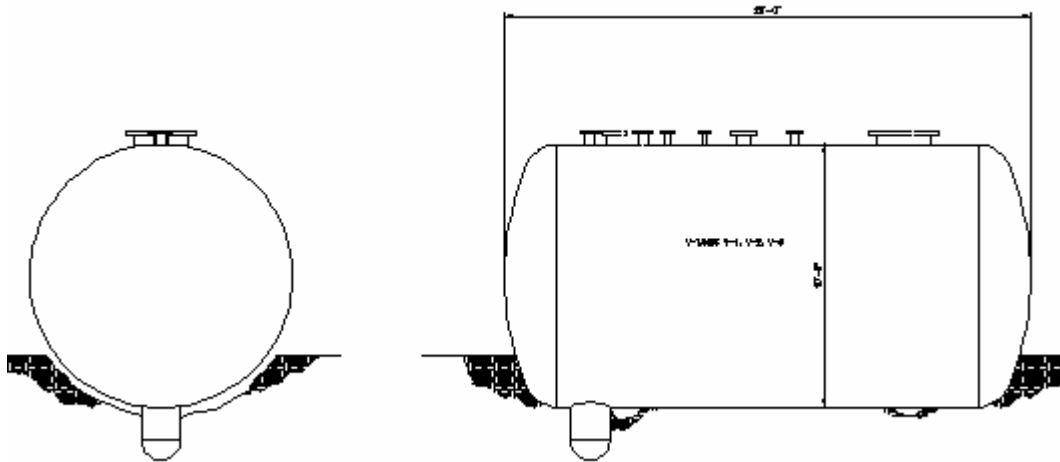
The demolition work contained in this EDF is considered "Consumer Grade", as specified in the Technical and Functional requirements document (TFR-278). All design and construction will comply with the quality requirements specified for this level of safety category.

5. NATURAL PHENOMENA HAZARDS PERFORMANCE CATEGORY

The system is classified as safety category consumer grade (CG) in accordance with the requirements of management control procedure MCP-540 titled *Documenting the Safety Category of Structures, Systems, and Components*. The safety basis for performing V-tank remedial activities is documented in the *Safety Analysis Report for Test Area North Operations SAR-208*. There are no special requirements regarding industrial or natural phenomena hazards. Normal industrial and environmental hazards will be routinely addressed per the work control process (the system performance category designation is PC 0).

6. STRUCTURE SYSTEM OR COMPONENT DESCRIPTION

The system is the temporary installation required for safely removing and treating the contents of Tanks V-1, V-2, V-3 and V-9 and preparing both the treated contents and empty tanks for disposal at the ICDF. The TAN remediation sites are known as TSF-09 (V-1, V-2, and V-3) and TSF -18 (V-9) at OU 1-10; these four tanks are commonly referred to as the V-tanks. The remediation is being conducted in accordance with the *Final Record of Decision for Test Area North, Operable Unit 1-10* (DOE-ID 1999) referred to as the ROD, and any appropriate amendments. Tanks V-1, V-2, and V-3 are identical stainless steel 10,000 gallon tanks 10 ft in diameter with a nominal 20 ft length, and located approximately 11 ft below grade.



V-Tank Elevation

7. DESIGN LOADS

The tank weight is based on a measured thickness of 1/2 " 304L stainless steel. This thickness results in an empty tank weight of 15,000 lbs. The total weight of the tanks with the solidified waste shall assume 15,000 lbs for the tank dead load plus 55,500 lbs for the waste, for a total of 71,000 lbs.

8. ASSUMPTIONS

The transport trailers were selected based on the assumption that they meet the minimum requirements for transport vehicles as specified by the ICP Packaging and Transportation Department. Evaluation of the trailers are not included in this EDF.

9. ACCEPTANCE CRITERIA

The transport evaluation shall be based on the tie-down requirements from the applicable sections of *49 CFR 393.102 Minimum Performance Criteria for Cargo Securement Devices and Systems*. Requirements for packaging, transporter and trailer, and transport plan and controls are not included in this evaluation.

49 CFR 393.102 Minimum Performance Criteria for Cargo Securement Devices and Systems:

49 CFR 393.102 (d) Equivalent Means of Securement: Cargo that is immobilized, or secured in accordance with the applicable requirements of 49 CFR 393.104 through 393.136 is considered as meeting the performance requirements of 393.102.

49 CFR 393.104 (a) General. (for information only)

All devices and systems used to secure cargo to or within a vehicle must be capable of meeting the requirements of 393.102.

(b) Prohibition on the use of damaged securement devices.

(c) Vehicle structures, floors, walls, decks, and tie-down anchor points and associated mounting pockets must be strong enough to meet the requirements of 393.102.

(d) Material for dunnage, chocks, cradles, shoring blocking and bracing. Materials used for dunnage, chocks, cradles, shoring blocking and bracing must not be damaged.

(e) Manufacturing standards for tie-down assemblies. Tie-down assemblies and other attachment or fastening devices used to secure articles of cargo to , or in commercial motor vehicles must conform to the following applicable standards:

Webbing: Web Sling and Tie down Association's Recommended Standard Specification for Synthetic Web Tie downs. (WSTDA-T1, 1998)

49 CFR 393.106 General Requirements for securing articles of cargo. (a) The rules of this section are applicable to the transportation of all types of articles of cargo, except commodities in bulk that lack structure or fixed shape and are transported in a tank, hopper or box that forms a part of the structure (fixed) of a commercial vehicle

(b) General. Cargo must be firmly immobilized or secured on, or within a vehicle by structures of adequate strength, dunnage or dunnage bags, shoring, tie downs or a combination of these.

(c) Cargo placement and restraint.

(1) Articles of cargo that are likely to roll must be restrained by chocks, wedges, a cradle or other equivalent means to prevent rolling. The means of preventing rolling must not be capable of becoming unintentionally unfastened or loose while in transit.

(d) Minimum strength of cargo securement devices and systems. The aggregate working load limit of any securement system used to secure an article or group of articles against movement must be at least one-half times the weight of the article or group. The aggregate working load limit is the sum of:

(1) One-half of the working load limits of each associated connector or attachment mechanism used to secure a part of the article of cargo to the vehicle.

(2) One-half of the working load limit for each end section of a tie-down that is attached to an anchor point

49 CFR 393.108 Determination of Working Load Limit. (a) The working load limit (WLL) of a tie-down, associated connector or attachment mechanism is the lowest working load limit of any of its components, or the anchor points to which it is attached. (b) The working load limit of tie-downs may be determined by using either the tie-down manufacturer's markings or tables in this section.

49 CFR 393.110 (a) in addition to the requirements of 393.106, the minimum number of tie-downs required to secure an article or group of articles against movement depends on the length of the article being secured, and paragraphs (b) and (c).

(b) When an article is not blocked or positioned to prevent movement in the forward direction by a headerboard, bulkhead, or other cargo that is positioned to prevent movement, or other appropriate blocking devices, it must be secured by at least:

- (1) One tie-down for articles 5 feet or less in length, and 1100 pounds or less in weight.
- (2) two tie-downs if the article is :
 - (i) 5-feet or less in length and more than 1100 pounds; or
 - (ii) Longer than 5-ft but less than or equal to 10-feet in length, irrespective of the weight,
- (3) two tie-downs if the article is longer than 10-feet, and one additional tie-down for every 10-feet of article length and fraction thereof beyond the first 10-feet.

10. SOFTWARE

Timber design for support cribbing utilized StruCalc 6.0, by Cascade Consulting Associates.

11. REFERENCES

- AISC, American Institute of Steel Construction, Manual of Steel Construction, Allowable Stress Design.
- Technical and Function Requirements (TFR-278) *T&FR for the Remediation of V-Tanks, TSF-09 and TSF-18, Operable Unit 1-10.*
- Safety Analysis Report for Test Area North Operations SAR-208.
- StruCalc 6.0, Version 6.00.7, Timber Design Software, Cascade Consulting Associates
- EDF-5595 TS-09/18 V Tanks Remediation Tank Lifting Design, P Bragassa, 3/05
- 49 CFR 393.100, Code of Federal Regulations, Federal Motor carrier Safety Administration. 9/27/02

12. CALCULATIONS

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TAN V Tanks Tie Down Calculations

Dimensional definitions:

$$\begin{aligned} \text{pcf} &= \frac{\text{lbf}}{\text{ft}^3} & \text{plf} &= \frac{\text{lbf}}{\text{ft}} & \text{psf} &= \frac{\text{lbf}}{\text{ft}^2} & \text{kip} &= 1000 \text{ lbf} & (\text{lbf} = \text{pound-force}) \\ \text{ksi} &= \frac{\text{kip}}{\text{in}^2} & \text{pli} &:= \frac{\text{lbf}}{\text{in}} & \text{sf} &:= \text{ft}^2 & \text{psi} &:= \frac{\text{lbf}}{\text{in}^2} \end{aligned}$$

Weight of the V-Tanks:(Ref EDF-5595) Using a measured thickness of 1/2" Stainless steel

Total Solidified waste weight: solid := 55500 lbf Cribbing weight (EDF-5595):

Maximum tank weight: EDF-5595 tank := 71000 lbf cribwt := 4000 lbf

Tank Length: 20-ft overall (nominal) length := 20 ft

Tank Tie-Down/Securement Criteria:

BBWI Packaging and Transportation Transport Plan has identified that Sections 393.104 through 393.136 will be utilized for the V-tank shipments. To accomplish these tie-down requirements, the following will be used:

Nylon/poly straps were selected by Packaging and Transportation to be used for securing the tanks. The 4" wide straps are free at one end to all usage with the winches provided on the trailer (seven sliding winches are provided on each side). The other end of the straps are provided with hooks for securing to the trailer frame. Each strap will run from the trailer winch over the tank to the opposite side. Each strap has a minimum capacity of 12,000 lbf each (WLL).

The minimum strength of the cargo securement devices and system per section 393.106 (d) shall be at least 1/2 times the weight of the article or group.

Total restrained weight: Tank+contents+cribbing+wrapping

$$\text{weighttotal} := 71000 \text{ lbf} + 4000 \text{ lbf} + 200 \text{ lbf} \quad \text{weighttotal} = 75200 \text{ lbf}$$

The minimum number of straps required: $75200 \text{ lbf} \cdot 0.5 = 37600 \text{ lbf}$

$$\frac{37600 \text{ lbf}}{12000 \text{ lbf}} = 3.133 \quad \text{therefore, if 4 straps minimum are used, the criteria is met.}$$

$$\frac{37600 \text{ lbf}}{4 \cdot 12000 \text{ lbf}} = 0.783 \quad \text{DC ratio}$$

Strap Requirements: Since the nominal tank length is 20-ft, the minimum strap requirements from 49 CFR 393.110 is

1 tie-down for the first 10-ft, and 1 for every 10-ft of length beyond,

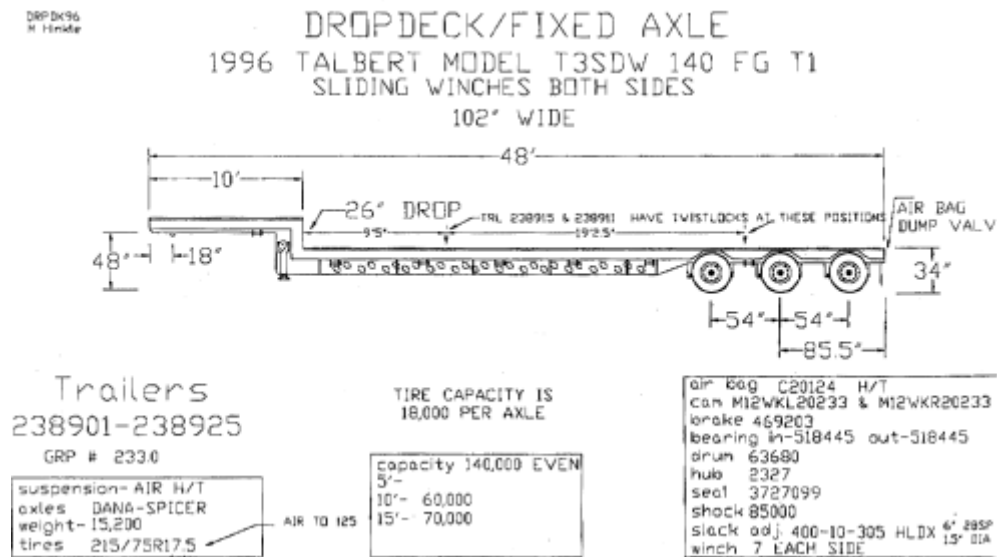
therefore:

minimum 2 tie downs required for 20-ft tank, however the minimum load requirements dictate that a minimum of four are required.

Web straps shall meet the requirements of the Web Sling and tie down Association's Recommended Standard Specification for Synthetic Web Tie downs (WSTDA-T1, 1998)

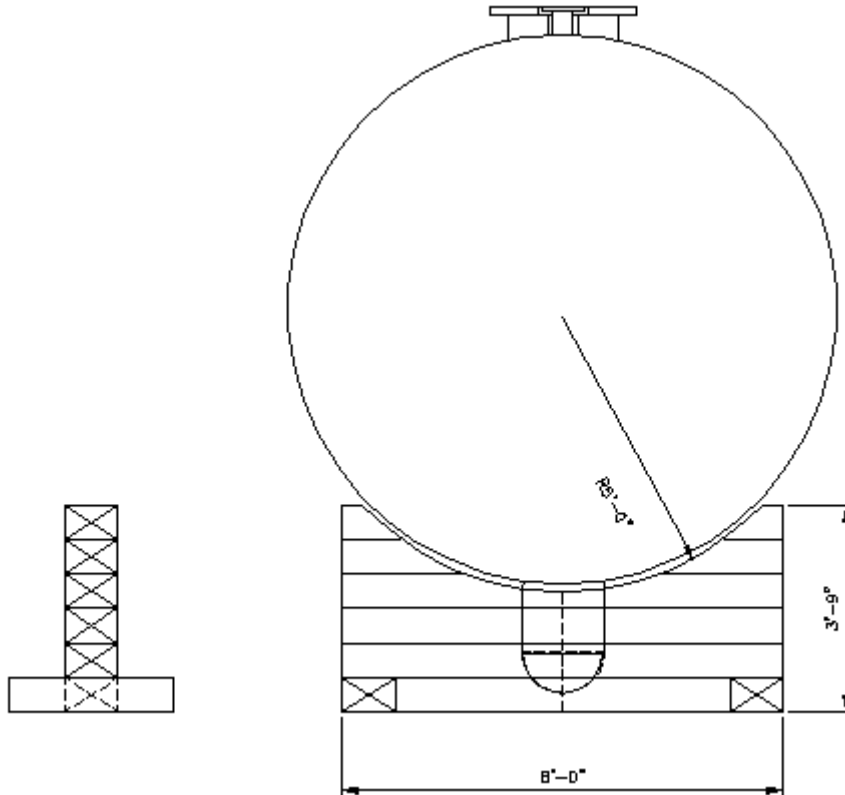
Straps shall have a minimum working Load Limit (WLL) of 12,000 lbs, each.

Transport Trailer Specifications



Tank Cribbing (Cradles) Design:

The cribbing design was performed as part of EDF-5595 and is included here for reference. Design cribbing to support tanks V-1, 2, 3 on the transport trailer, or in a staging area. Cribbing shall be designed to be used on a surface with a bearing capacity of at least 3000 psf. Tanks shall be assumed to be fully loaded with the solidified material (55,500 lb payload). Seismic and wind will be ignored, since the tanks will be tied down while on the trailer.



Weights: Tankweight := 15000lbf (rounded up)
solidwaste := 55500lbf

stageweight := Tankweight + solidwaste stageweight = 70500lbf

for miscellaneous tarps, etc, round up to 71,000 lbf

weight := 71000lbf

If 8x12 nominal DF-L (N) timbers are used and the length of each saddle is limited to 8' due to the maximum trailer width.

The actual dimensions for 8x12 timber is: 7.5" x 11.5"

The bearing area for a single saddle, 8' long and neglecting outriggers is: $11.5\text{in} \cdot 8\text{ft} = 7.667\text{ft}^2$

Number of saddles required for 3000 psf bearing area: $7.667\text{ft}^2 \cdot 3000\text{psf} = 23001\text{lbf}$

$$\frac{71000\text{lbf}}{23001\text{lbf}} = 3.087 \quad \text{or three saddles required if evenly distributed.}$$

center timber would however see 5/8 of the load: $71000\text{lbf} \cdot \frac{5}{8} = 44375\text{lbf}$

$$\frac{44375\text{lbf}}{7.667\text{ft}^2} = 5787.792\text{psf} \quad \text{which would exceed the 3000 psf bearing capacity}$$

therefore, use four supports for overall stability and load variations.

Using a beam distribution with four supports, to determine the reaction at each saddle:

if a 14ft dimension is assumed as an overall length and even spacing then:

$$w := \frac{71000\text{ lbf}}{14\text{ ft}} \qquad \frac{14\text{ft}}{3} = 4.667\text{ft}$$

$$\text{end support load:} \quad R1 := \frac{4 \cdot w \cdot 4.667\text{ft}}{10} \qquad R1 = 9467.343\text{lbf}$$

$$\text{interior supports:} \quad R2 := \frac{11 \cdot w \cdot 4.667\text{ft}}{10} \qquad R2 = 26035.193\text{lbf}$$

$$\frac{R2}{7.667\text{ft}^2} = 3395.747\text{psf} \quad \text{although over the 3000 psf, the outrigger skid beams were neglected and would reduce the bearing load. ok}$$

Timber capacities: Douglas fir Larch North has a bearing compression design values of 625 psi for compression perpendicular to the grain.

arc length supporting tanks approximately 8.166 ft from autocad model:

$$f_c := 625\text{psi} \quad \text{allowable load per foot} \quad 625\text{psi} \cdot 7.5\text{in} \cdot 12\text{in} = 56250\text{lbf}$$

$$\text{Bearing Surface Area:} \quad 7.5\text{in} \cdot 8.166\text{ft} = 5.104\text{ft}^2$$

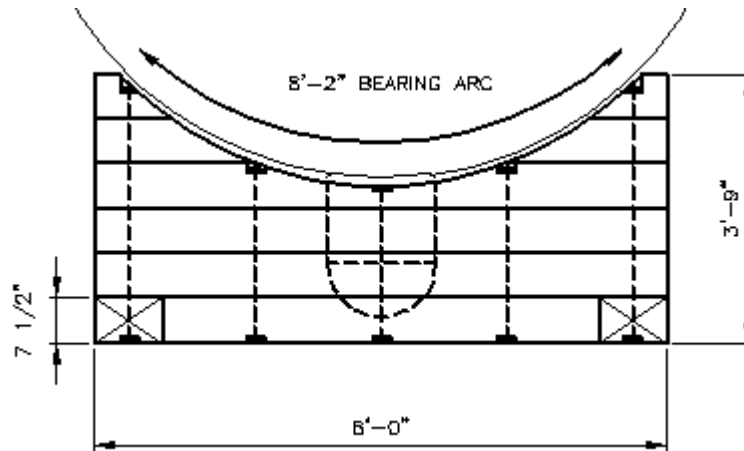
$$\text{for 2 saddles:} \quad 71000 \frac{\text{lbf}}{2} = 35500\text{lbf} \qquad F_c := \frac{35500\text{lbf}}{5.104\text{ft}^2} \qquad F_c = 48.301\text{psi}$$

Ok timbers will not crush. Use 4 saddles per tank.

$$DC := \frac{48.3\text{ psi}}{625\text{ psi}} \quad DC = 0.077$$

Cribbing Saddle connections:

Long threaded rods will be used to tie the timbers together



If five (5) 3/4 inch A36 threaded rods are used to tie the 8x12 timbers together, the total shearing strength of the assembly would be:

AISC Table 1-D for A307 rod, 3/4-inch $F_v := 4400 \text{ lbf}$ $5 \cdot F_v = 22000 \text{ lbf}$ per saddle

The lateral force requirement for cargo securement systems of 49 CFR 393.102 is 0.5g and for forward or rearward is 0.8 g's. The tanks will be secured with tie downs, but check shear capability of saddles only. Neglect friction between timbers and check bolts:

$$\text{Forward: } \frac{R2 \cdot .8}{2} = 10414.077 \text{ lbf} \quad \text{lateral: } \frac{R2 \cdot .5}{2} = 6508.798 \text{ lbf}$$

per saddle < 22,000 lbf ok

bolts are capable of resisting shear. $\text{max DC } \frac{10414 \text{ lbf}}{22000 \text{ lbf}} = 0.473$

Check Bearing force at bolts on timbers:

Bearing on timbers: Ref ANSI/NFPA NDS National Design Standard, Section 8.2 single shear connections. The bearing forces from bolts on timbers: $\frac{10414 \text{ lbf}}{5} = 2082.8 \text{ lbf}$

Table 8A Dowel Bearing Strength: for bearing strength parallel to grain for DFL-n, $f_e = 5500 \text{ psi}$

Equation 8.2.1 for yield mode Im (bearing dominate yield of wood fibers)

$$Z := \frac{D \cdot t_m \cdot F_{em}}{4 \cdot K} \quad D := .75 \text{ in (bolt diam)} \quad t_m := 7.5 \text{ in (thickness of 8x12)}$$

$F_{em} := 2500 \text{ psi}$ (dowel bearing strength perpendicular) $K := 1$ (no angle, direct shear)

$$Z := \frac{D \cdot t_m \cdot F_{em}}{4 \cdot K} \quad Z = 3515.625 \text{ lbf (allowable shear values at bolt holes} > 2083 \text{ lbf) ok}$$

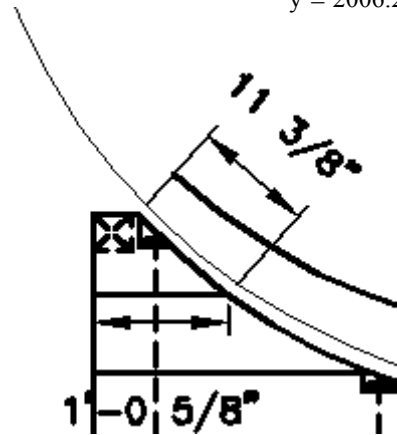
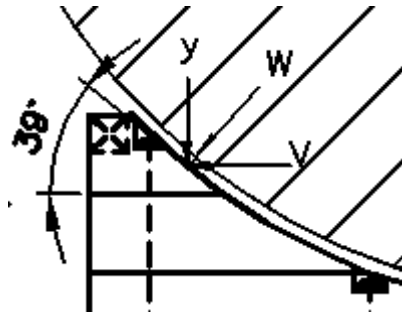
Shear Between timbers due to radial loading

for 4 saddles: the interior saddles reactions: $R2 = 26035.193 \text{ lbf}$

the radial dimension of the bearing area
determined from autocad model: $L_r := 8.166 \text{ ft}$ $\frac{R2}{L_r} = 3188.243 \text{ plf}$

horizontal shear component, worst angle at approx 50 degrees near top of saddle. This angle drops significantly towards the bottom of the tank.

$v := \cos(39\text{deg}) \cdot 3188 \text{ plf}$ $v = 2477.541 \text{ plf}$ vertical component: $y := \sin(39\text{deg}) \cdot 3188 \text{ plf}$
 $y = 2006.273 \text{ plf}$

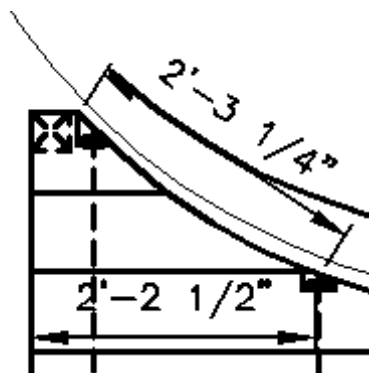


friction coef for wood: .35 (Modern College Physics, 6th ed H.E. White pg 118)

friction force: between timbers $0.35 \cdot y = 702.196 \text{ plf}$

At top timber: total lateral force: $v \cdot 11.375 \text{ ft} = 2348.503 \text{ lbf}$
friction resistance: $702 \text{ plf} \cdot 1 \text{ ft} = 702 \text{ lbf}$ ok $DC := \frac{2349 \text{ lbf} - 702 \text{ lbf}}{4400 \text{ lbf}}$
rod shear strength: 4.4 kips

$DC = 0.374$



second section:

lateral force: $v \cdot 2.25 \text{ ft} = 5574.468 \text{ lbf}$

friction: $702 \text{ plf} \cdot 2.25 \text{ ft} = 1579.5 \text{ lbf}$

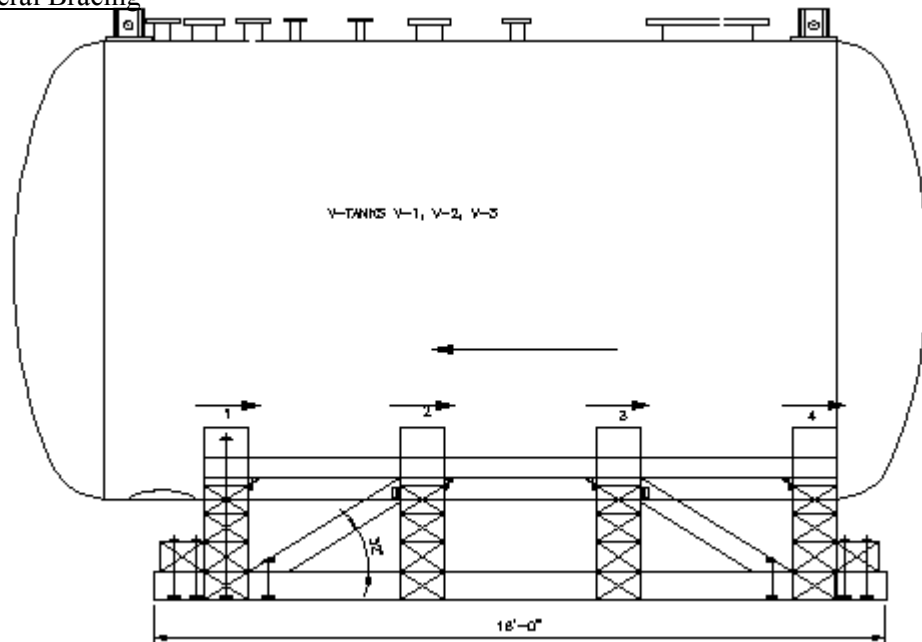
net := $4611 \text{ lbf} - 1924 \text{ lbf}$ net = 2687 lbf

rod shear strength 4.4 kips ok

$DC := \frac{5575 \text{ lbf} - 1580 \text{ lbf}}{4400 \text{ lbf}}$ $DC = 0.908$

conservative since horizontal angle is reduced to approximately 30 deg, but worst case load is assumed.

Lateral Bracing



Lateral Force: if the 0.8g force due to truck acceleration/stopping is assumed then the lateral force would be:

$$\text{Plat} := 71000 \text{bf} \cdot 0.8 \quad \text{Plat} = 56800 \text{ lbf}$$

If only the braces in compression are use, then two braces would resist this load

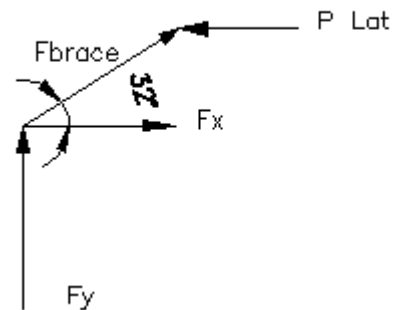
$$\text{Fbrace} := \text{Plat} \cdot \cos(32\text{deg})$$

$$\text{Fbrace} = 48169.132 \text{bf}$$

$$\text{for two braces: } \frac{\text{Fbrace}}{2} = 24084.566 \text{ lbf}$$

$$\text{Fx} := 24084.566 \cdot \cos(32\text{deg}) \quad \text{Fx} = 20425.238 \text{bf}$$

$$\text{Fy} := 24084.566 \cdot \sin(32\text{deg}) \quad \text{Fy} = 12763.105 \text{ lbf}$$



Check Brace Using StruCalc 6.0 and 24.1 kips

Column[2000 International Building Code (97 NDS)] Ver: 6.00.7
By: Pat Bragassa , Bechtel BWXT Idaho on: 03-23-2005 : 10:29:20 AM
Project: Vtank Cribbing - Location:
Summary:
5.5 IN x 5.5 IN x 2.83 FT / #2 - Douglas Fir-Larch (North) - Dry Use
Section Adequate By: 12.7%

Vertical Reactions:

Live:	Vert-LL-Rxn=	24083	LB
Dead:	Vert-DL-Rxn=	24	LB
Total:	Vert-TL-Rxn=	24107	LB

Axial Loads:

Live Loads:	PL=	24083	LB
Dead Loads:	PD=	0	LB
Column Self weight:	CSW=	24	LB
Total Loads:	PT=	24107	LB
Eccentricity (X-X Axis):	ex=	0.00	IN
Eccentricity (Y-Y Axis):	ey=	0.00	IN
Axial Duration Factor:	Cd-Axial=	1.33	

Column Data:

Length:	L=	2.83	FT
Maximum Unbraced Length (X-X Axis):	Lx=	2.83	FT
Maximum Unbraced Length (Y-Y Axis):	Ly=	2.83	FT
Column End Condition:	Ke=	1.0	

Calculated Properties:

Column Section (X-X Axis):	dx=	5.50	IN
Column Section (Y-Y Axis):	dy=	5.50	IN
Area:	A=	30.25	IN ²
Section Modulus (X-X Axis):	Sx=	27.73	IN ³
Section Modulus (Y-Y Axis):	Sy=	27.73	IN ³
Slenderness Ratio:	Lex/dx=	6.17	
	Ley/dy=	6.2	

Properties For: #2- Douglas Fir-Larch (North)

Compressive Stress:	Fc=	700	PSI
Modulus of Elasticity:	E=	1300000	PSI
Bending Stress (X-X Axis):	Fbx=	725	PSI
Bending Stress (Y-Y Axis):	Fby=	725	PSI

Adjusted Properties:

Fc':	Fc'=	913	PSI
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Adjustment Factors: Cd=1.33 Cp=0.98

Column Calculations (Controlling Case only):

Controlling Load Case: Axial Total Load only (L + D)			
Compressive Stress:	Fc=	797	PSI
Allowable Compressive Stress:	Fc'=	913	PSI

Use a 6x6 DFL timber for brace: Allowable stress = 913 psi, actual = 797 psi ok.

$$DC := \frac{797 \text{ psi}}{913 \text{ psi}} \quad DC = 0.873$$

Brace connection:

for 3/4 inch A307 rod, and since this is an impact force, use yield strength:

$$Ult := 58\text{ksi} \quad A_{\text{rod}} := \pi \cdot \left[\left(\frac{3}{4} \text{in} \right)^2 \right] \quad A_{\text{rod}} = 0.442 \text{in}^2$$

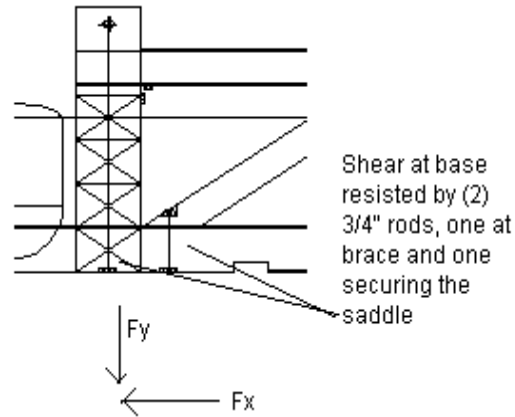
$$F_y := 36\text{ksi}$$

shear at base will be resisted by two 3/4-in rods, one through the brace and one through the saddle.

$$\text{shear per rod:} \quad \frac{F_x}{2} = 10212.619 \text{bf}$$

$$\text{stress per rod:} \quad \frac{10212.619 \text{bf}}{A_{\text{rod}}} = 23.117 \text{ksi}$$

less than yield stress, ok



Check Bearing force at bolts on timbers:

Bearing on timbers: Ref ANSI/NFPA NDS National Design Standard, Section 8.2 single shear connections and considering the 8x12 skid. The diagonal brace will transfer the shear to the saddle and skid by contact bearing even if the brace bolt fails.

Table 8A Dowel Bearing Strength: for bearing strength parallel to grain for DFL-n, $f_e = 5500$ psi

Equation 8.2.1 for yield mode Im (bearing dominate yield of wood fibers)

$$Z := \frac{D \cdot t_m \cdot F_{em}}{4 \cdot K} \quad D := .75 \text{in} \quad (\text{bolt diam}) \quad t_m := 7.5 \text{in} \quad (\text{thickness of } 8 \times 12)$$

$$F_{em} := 5500 \text{psi} \quad (\text{dowel bearing strength}) \quad K := 1 \quad (\text{no angle through skid})$$

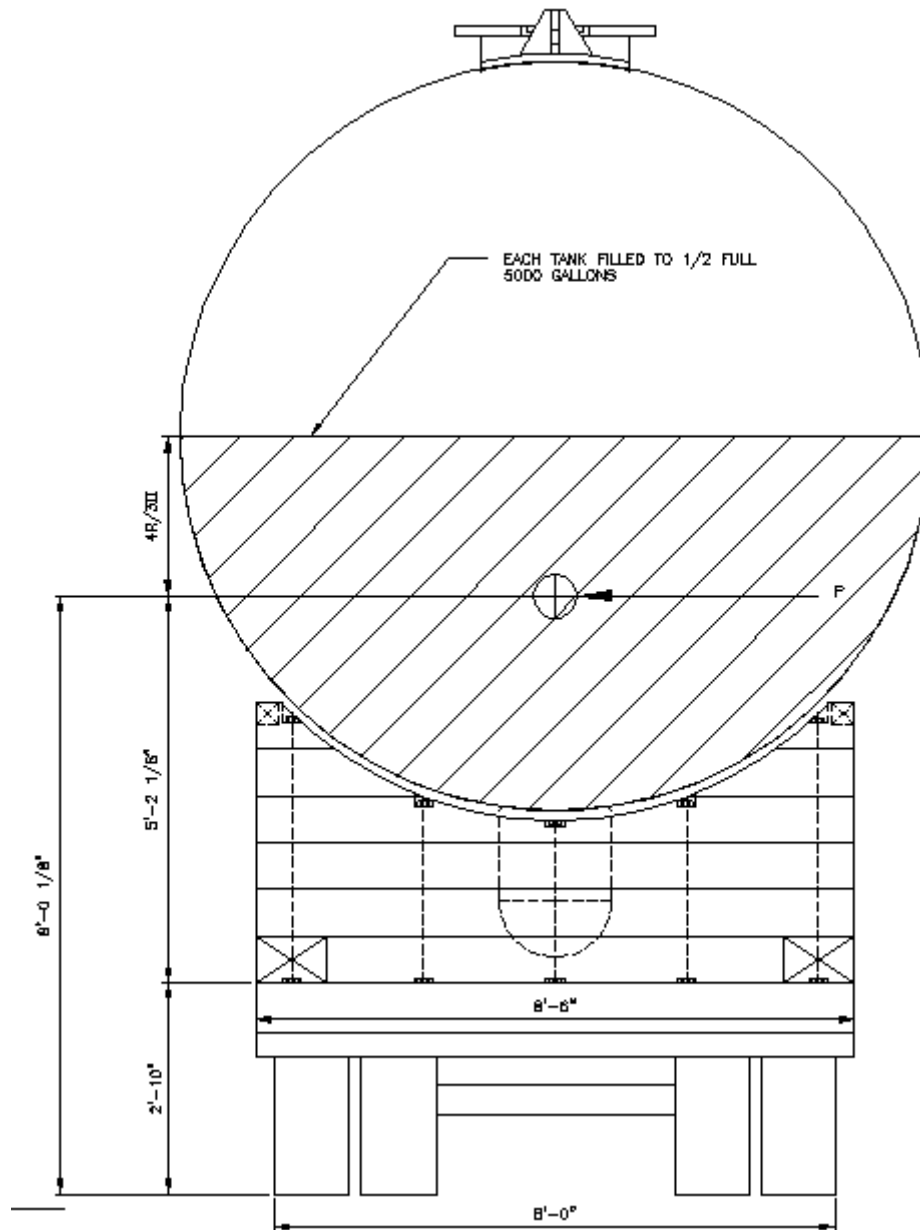
$$Z := \frac{D \cdot t_m \cdot F_{em}}{4 \cdot K} \quad Z = 7734.375 \text{ lbf} \quad (\text{allowable shear values}) \quad \text{less than } 10,212 \text{ lbs}$$

If an additional 2 bolts are added, then 4 bolts will resist the shear:

$$\frac{F_x}{4} = 5106.311 \text{bf} \quad \text{ok} < Z = 7734 \text{ lbf} \quad DC := \frac{5106 \text{ lbf}}{7734 \text{ lbf}} \quad DC = 0.66$$

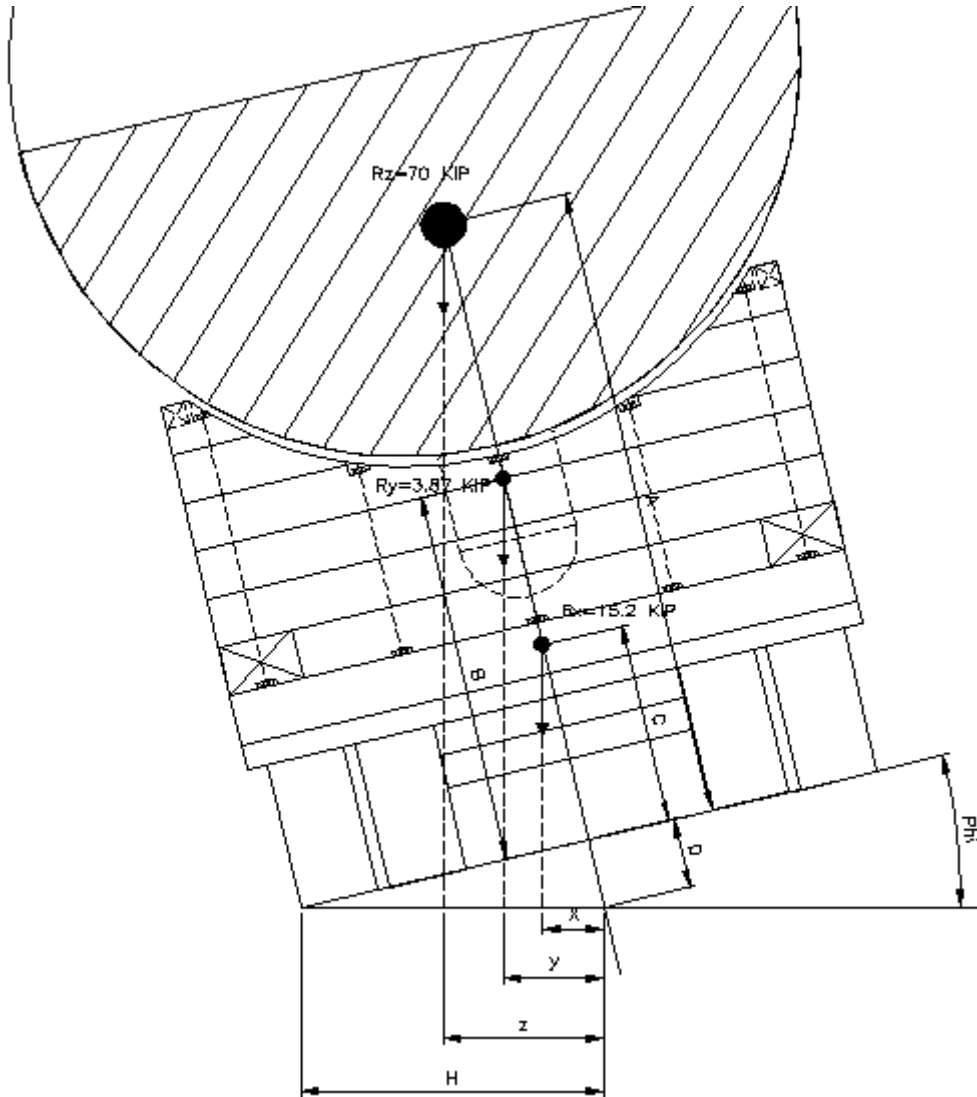
add 2 bolts and block to the opposite side of saddle to resist shear.
(Bearing strength of wood governs)

Check Stability of Transport Trailer:



Vertical Forces:

Tankdead := 15000lbf Tank contents: contents := 55000 lbf
 cribbing weight: 8x12 df-L timbers from NDS Supplement, weight approx 21 plf
 $(8\text{ft} \cdot 4 + 6\text{ft}) \cdot 21\text{plf} = 798 \text{ lbf}$ per saddle
 for 4 saddles: $800\text{lbf} \cdot 4 = 3200 \text{ lbf}$ Skids: $16\text{ft} \cdot 21\text{plf} \cdot 2 = 672 \text{ lbf}$
 cribwt := $672\text{lbf} + 3200\text{lbf}$ cribwt = 3872 lbf Trailerwt := 15200lbf



$$R_z := 70 \text{ kip} \quad R_y := 3.87 \text{ kip} \quad R_x := 15.2 \text{ kip}$$

$$\theta := 25.5 \text{ deg} \quad \phi := 90 \text{ deg} - \theta \quad A := 10 \text{ ft} \quad B := 3.83 \text{ ft} \quad C := 2 \text{ ft}$$

$$D := 4 \text{ ft} \cdot \tan(\theta) \quad \phi = 64.5 \text{ deg} \quad x := (C + D) \cdot \cos(\phi) \quad y := (D + B) \cdot \cos(\phi) \quad z := (D + A) \cdot \cos(\phi)$$

$$H := \frac{4 \text{ ft}}{\cos(\theta)} \quad A_x := H - x \quad A_y := H - y \quad A_z := H - z$$

$$M_z := R_z \cdot A_z \quad M_y := R_y \cdot A_y \quad M_x := R_x \cdot A_x \quad M_a := M_z + M_y + M_x$$

The trailer will not tip as long as the sum of the moments (M_a) are positive.

$$M_a = 746.701 \text{ lbf} \cdot \text{ft} \quad \text{This proves the trailer will not tip up to an angle of 25 degrees}$$

Transport Design Summary:

Tankwt := 71000lbf Trailerwt = 15200 lbf cribwt = 3872 lbf

Each tank will be supported by (4) saddles (cradles), braced together in a frame. The saddles were designed to support the tank weight of 71,000 lbs on a bearing surface of 3000 psf. The saddles are designed to resist lateral forces of 0.8 g forward and rearward and 0.5 g sideways. Friction pads will be placed between the tank and support saddles to transfer lateral forces from the tank to the saddles. These friction pads shall have a lateral load resistance rating of 0.8g minimum. Longitudinal forces are transferred from the top of the saddle to the base by braces. Friction mats are placed between the saddle base skid and trailer bed to transfer forces to the trailer structure. Friction mats shall have a minimum lateral load resistance of 0.8 gs.

Saddle Design Maximum Demand Capacity ratio: 0.87 (braces)

Stability: The tanks loaded on the trailers will be stable up to an angle of 25 degrees. Since the crown (grade) of the roadways is less than 5 degrees, a margin of safety is provided that is reasonable.

